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TEMPERATURE DEPENDENCE OF THE DIELECTRIC CONSTANT OF QUARTZ POL--ETC(U)
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Temperature Dependence of the Dielectric Constant of Quartz Polymide

by
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Research Department
and
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DECEMBER 1977

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Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center
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FOREWORD

This report is the result of a radome measurement program performed for the Weapons Development Department, Code 39. This is a final report and represents work performed during March and April 1977. The funding was supplied under AIRTASK Project No. A03P-03P2/008C/7W055/-001.

This report has been reviewed for technical accuracy by Mr. D. J. White.

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14 September 1977

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(U) *Temperature Dependence of the Dielectric Constant of Quartz Polymide*, by James W. Battles and Karl D. Kuehn. China Lake, Calif., Naval Weapons Center, December 1977. 6 pp. (NWC TP 5983, publication UNCLASSIFIED.)

(U) A doppler generator was used to measure the complex dielectric constant of quartz polymide at 35 GHz from room temperature to 840°F (450°C).

INTRODUCTION

A quartz polymide sample was provided the Naval Weapons Center by the Vaught Corporation for the purpose of measuring the temperature dependence of its dielectric constant at 35 GHz. The method used to measure the dielectric constant is new and will be briefly described.

EXPERIMENTAL METHOD

An object moving with a known velocity in a waveguide creates a unique doppler frequency for each electromagnetic wavelength in the normal operating band of the waveguide. The measured doppler frequency can be used to calculate the carrier frequency. When each half of the waveguide is filled with a dielectric leaving a narrow slit for the post, then the doppler frequency change caused by the dielectric can be used to calculate the dielectric constant.

Figure 1 is a drawing of a doppler generator that will work as described above. Since the waveguide circle is a known diameter and the rotor and post rotate at a known frequency, the real part of the dielectric constant, K_e, will be given by

$$K_e = [(f_c/f_\tau)^2 + (f_d/f_\tau)^2(C/4\pi r f_o)^2]A \quad , \qquad (1)$$

where

f_c = waveguide cutoff frequency

f_τ = carrier frequency

f_d = doppler frequency

C = velocity of light

r = radius of waveguide circle

f_o = rotor rotational frequency

$$A = \frac{\text{cross sectional area of waveguide}}{\text{cross sectional area of dielectric}} \quad .$$

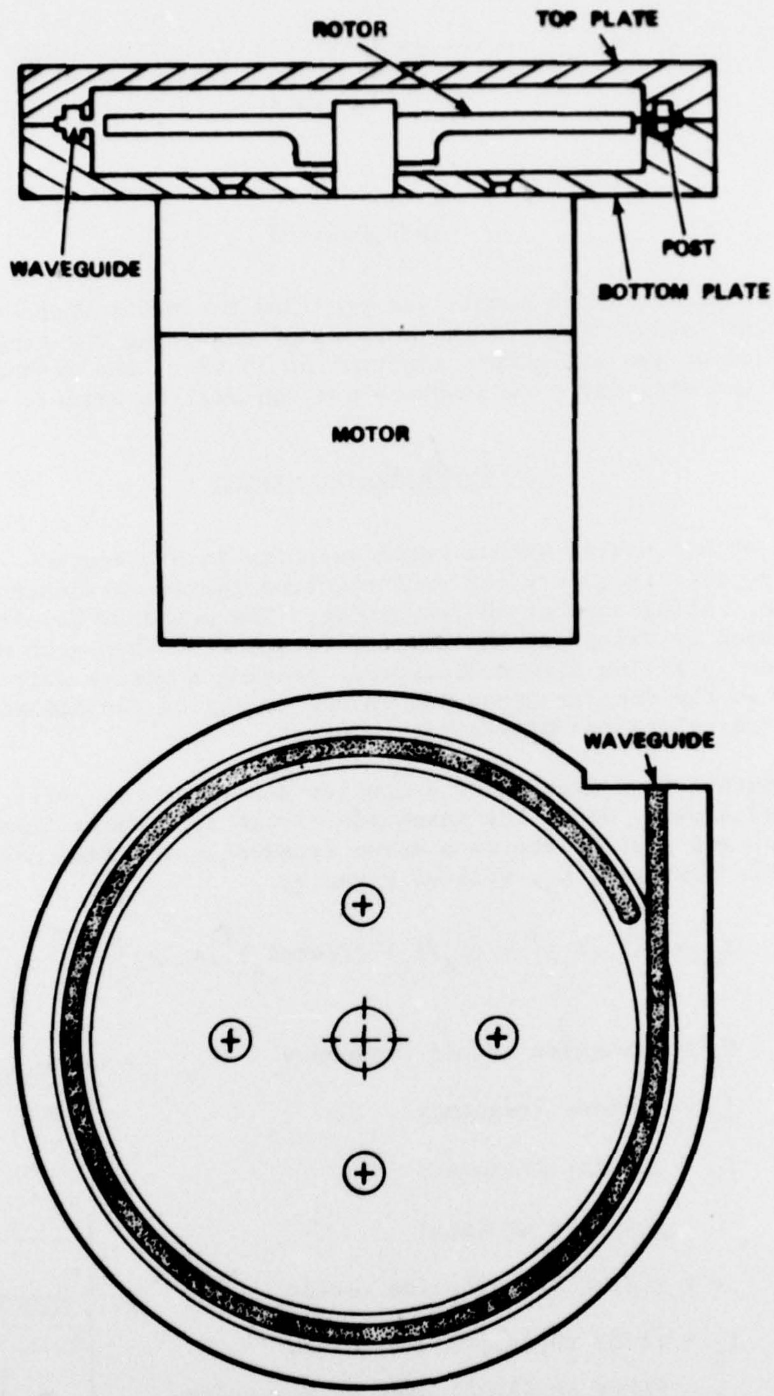

FIGURE 1. Basic Design of a Waveguide Doppler Generator.

The loss tangent of the dielectric can be determined from the amplitudes of the doppler signal for two or more different path lengths in the dielectric. Figure 2 shows two positions of the post as it is being rotated in the dielectric filled doppler generator. The doppler signal from the post in position A has required the carrier to traverse the dielectric length in both directions. Thus, if we measure the amplitudes of the signal envelope, the post positions A and B, we can calculate the loss tangent from

$$\tan\delta = -\frac{\ln R}{2\omega\ell\sqrt{\varepsilon'\mu_0}} \quad , \qquad (2)$$

where

$$R = \frac{\text{signal amplitude at A}}{\text{signal amplitude at B}}$$

ℓ = arc length from point A to point B through the dielectric

$\omega = 2\pi f_\tau$

$\varepsilon' = K_e\varepsilon_0$; $\varepsilon_0 = 8.854 \times 10^{-12}$

$\mu_0 = 4\pi \times 10^{-12}$.

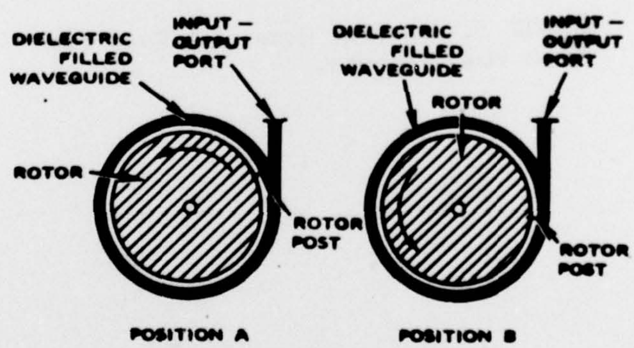

FIGURE 2. Position A Indicates the Post at the Farthest Point in the Dielectric Waveguide from the Waveguide Port; Position B Indicates the Post Near the Waveguide Port. The signal envelope amplitudes at positions A and B can be used to calculate the loss tangent.

A doppler generator was designed and built that would keep the rotor bearing and the motor cool during the temperature cycle (see

Figure 3). A cooling gas (98% N; 2% H) was used to keep the bearings cool and was vented out through the waveguide. The flow rate was 3 ml/sec. The 2% H was used to keep the copper waveguide walls clean of oxides. Figure 4 is a schematic diagram of the test setup.

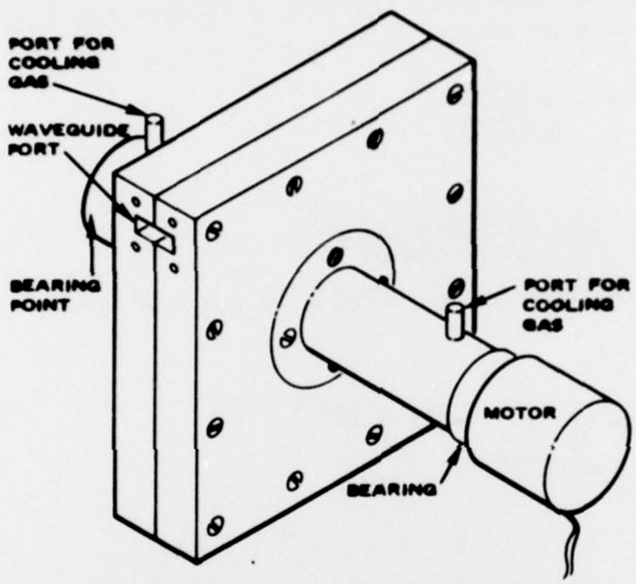

FIGURE 3. Doppler Generator Used for These Measurements.

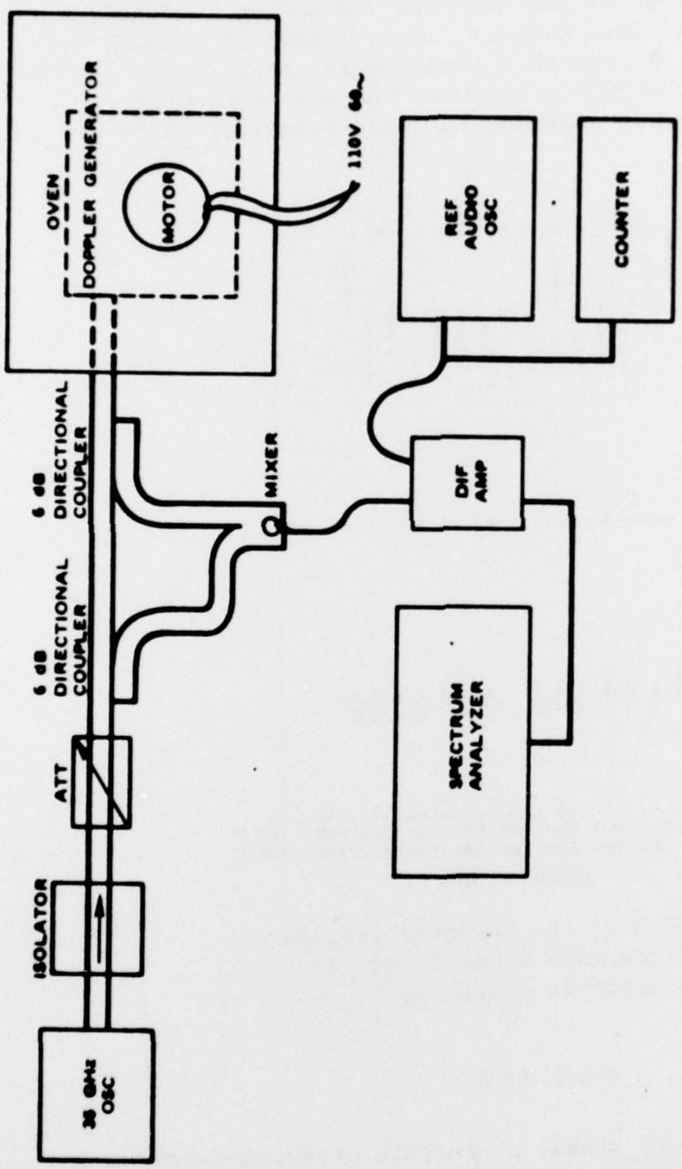

FIGURE 4. Schematic Diagram of the Test Setup.

RESULTS

Data were taken over the temperature range 70 to 840°F (21 to 449°C). Figure 5 is a graph of the measured dielectric constant, K_e, (using Equation 1) and the loss tangent, tanδ, (using Equation 2) as a function of temperature. K_e for this temperature range is 3.00 ± 0.005. Tanδ is best described by 0.0034 + 0.0005. The main source of error during these measurements was assuming the line frequency to be a constant 60 Hz.

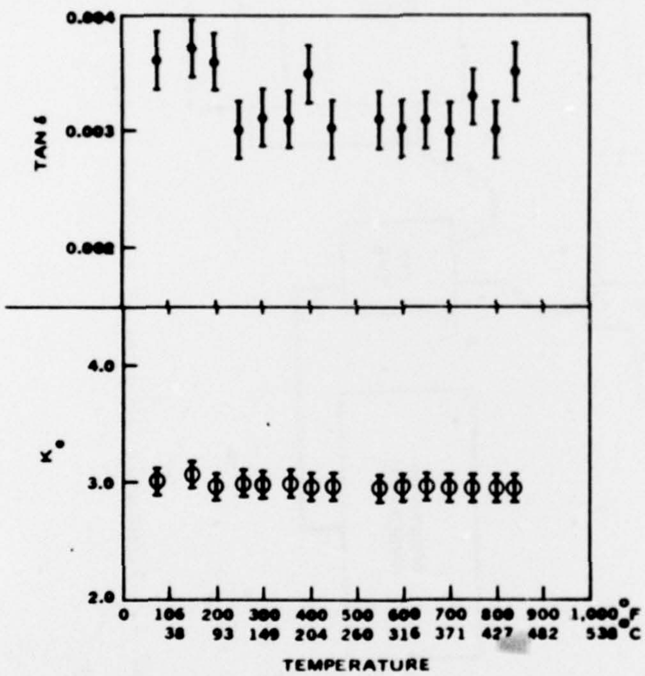

FIGURE 5. Graph of the Measured Temperature Dependence of the Loss Tangent and the Real Part of the Dielectric Constant.

CONCLUSIONS

Quartz polymide has very stable dielectric properties over this temperature range. It should be noted that no oxygen was present near the quartz polymide during these tests. Thus, it may be necessary to heat the quartz polymide in air for a fixed period of time at each temperature and then cool the sample to room temperature for the dielectric constant measurements. In this way, the copper waveguide would not be heated and there would be no waveguide oxidation problem.